

An Estimate of the Vertical Variability of Temperature at KSC Launch Complex 39-B

James Brenton

Jacobs ESSSA, MSFC Natural Environments Branch

7 September 2017

james.c.brenton@nasa.gov

Purpose and Data

- Purpose:
 - The purpose of this analysis is to determine the vertical variability of the air temperature below 500 feet at Launch Complex (LC) 39-B at Kennedy Space Center (KSC). This analysis utilizes data from the LC39-B Lightning Protection System (LPS) Towers and the 500 foot Tower 313. The results of this analysis will be used to help evaluate the ambient air temperature Launch Commit Criteria (LCC) for the Exploration Mission 1 launch.
- Data:
 - Data for this analysis came from quality controlled databases generated by EV44.
 - Weather Information Network Display System (WINDS) Tower 397 (LC39-B LPS):
 - 1 minute data, Period of record: 2011-2015
 - All temperatures recorded at 132, 257, 387, and 457 feet from the upwind tower.
 - WINDS Tower 313:
 - 5 minute data, Period of record: 1995-2008
 - All temperatures recorded at 204 and 492 feet, from the upwind sensor.
 - Tower 313 was used for its longer period of record. The data from Tower 313 is within a reasonable proximity to LC 39-B (approximately 2.18 miles).

Data



Methodology

- Find timestamps with concurrent temperatures at each height.
- Find maximum, minimum, mean, median, and STD of temperatures at each height.
- Calculate temperature deltas between heights from each data set:

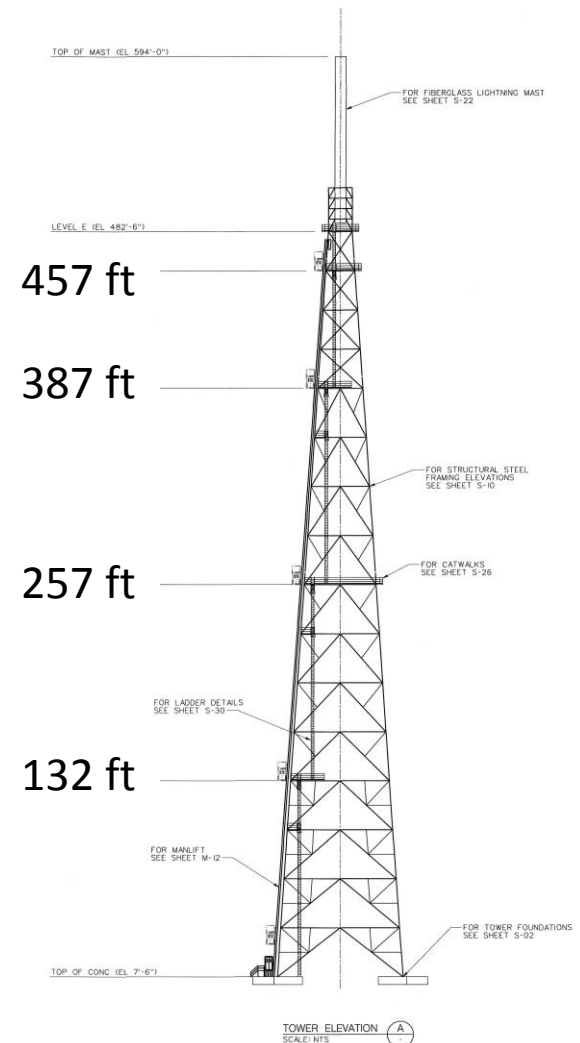
$$\Delta T = T_L - T_U$$

- For this study, a negative temperature delta (the temperature at the upper height is greater than the temperature at the lower height) will be defined as an inversion. A positive temperature delta (the temperature at the upper height is less than the temperature at the lower height) will be defined as a lapse rate.
- Calculate a variety of percentile envelopes (90%, 95%, 99%) of temperature deltas for one degree temperature bins as recorded at the lower height. The envelopes are plotted on a scatter graph of temperature at lower height versus the temperature delta. A histogram with the same axes is used to show the distribution of temperatures and their respective temperature deltas.

Tower 397 Statistics in Fahrenheit (F)

Height	Min	Max	Mean	Median	STD
132 ft	32.09	93.69	72.84	73.76	7.96
257 ft	31.91	93.07	72.6	73.58	7.77
387 ft	30.79	91.99	72.36	73.35	7.83
457 ft	30.56	91.81	72.19	73.13	7.81

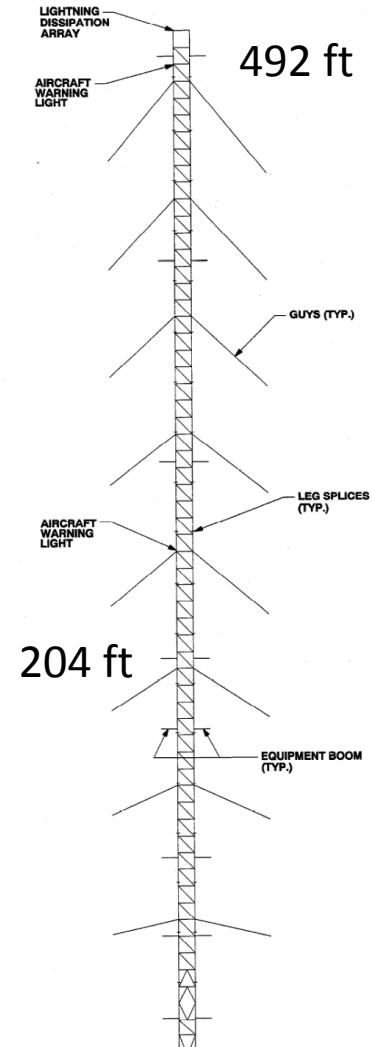
- The mean temperature at each height is approximately 72 F.
- The median temperature at each height is approximately 73 F.



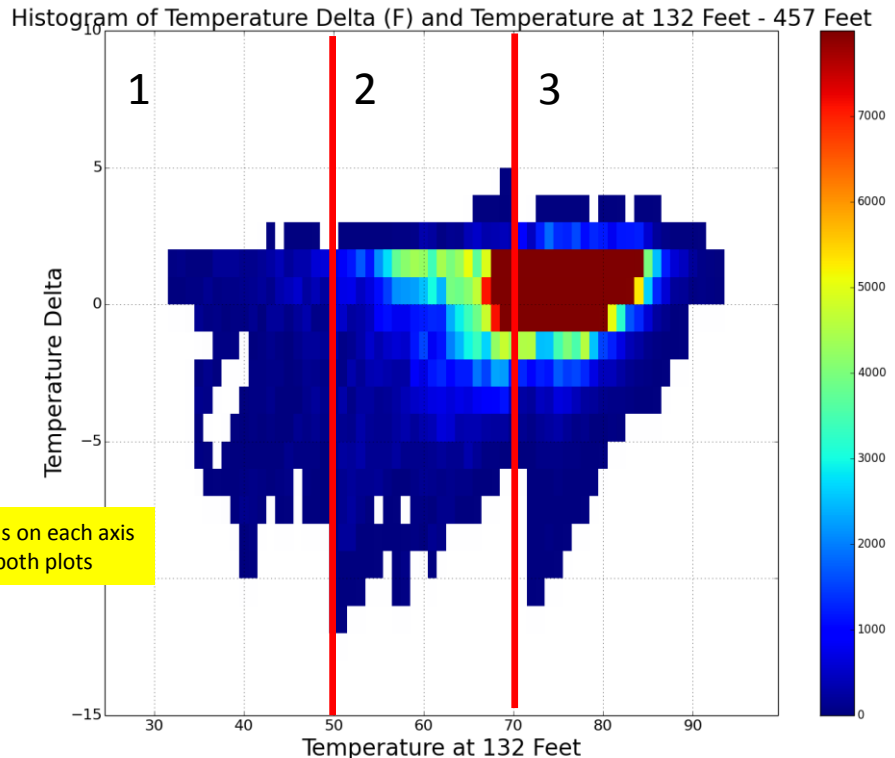
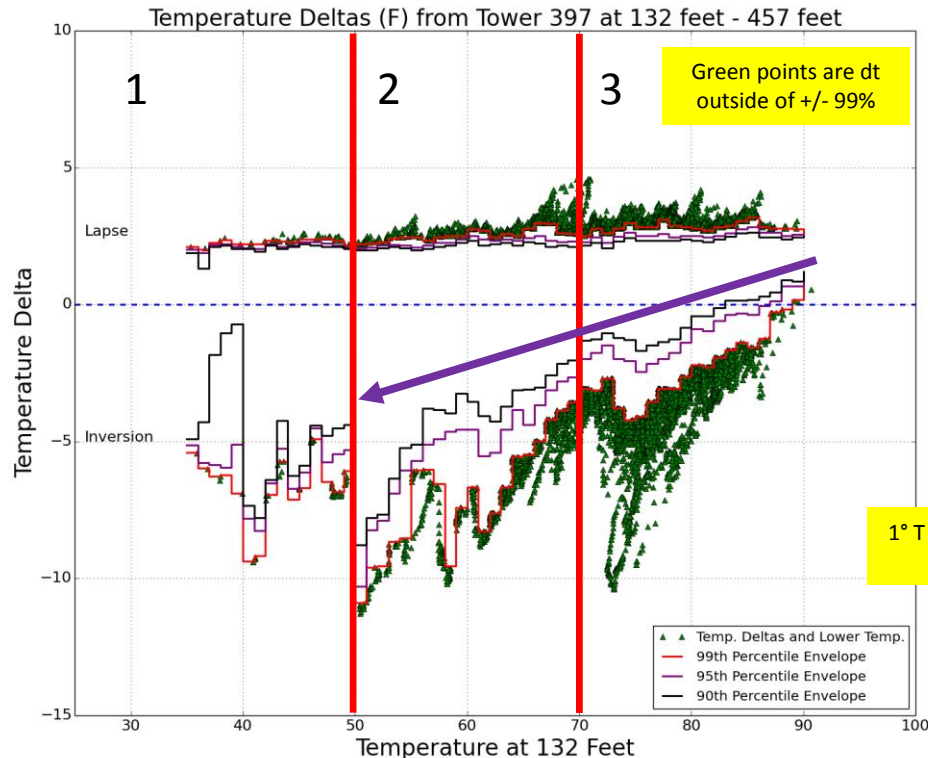
Tower 313 Statistics in Fahrenheit (F)

Height	Min	Max	Mean	Median	STD
204 ft	27.50	97.16	72.42	74.12	9.00
492 ft	28.04	95.18	71.63	73.22	8.71

- Tower 313 reports less than one degree difference between the mean values from both heights. Tower 313 reports a less than one degree difference between the median values from both heights.
- The difference between the minimum values of temperature are less one degree.
- Tower 313 has higher maximum and lower minimum values than Tower 397.
- All heights from both towers have a mean temperature within one degree (+/-) of 72 degrees.



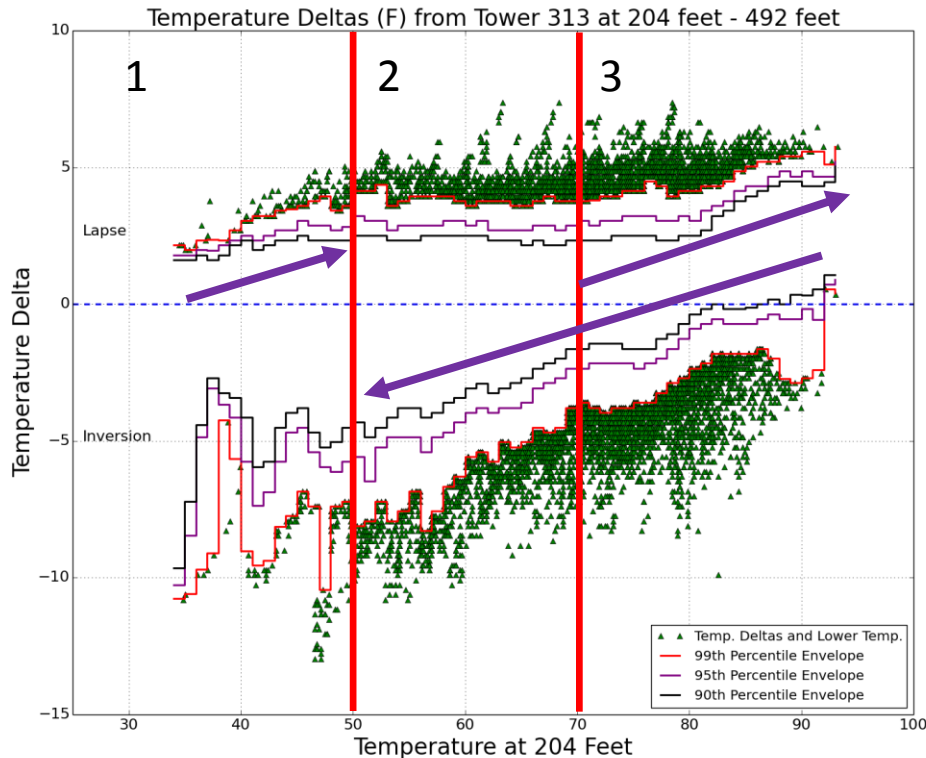
COMBINED CHARTS 7-9: Tower 397 Temperature Deltas (F) 132 ft – 457 ft



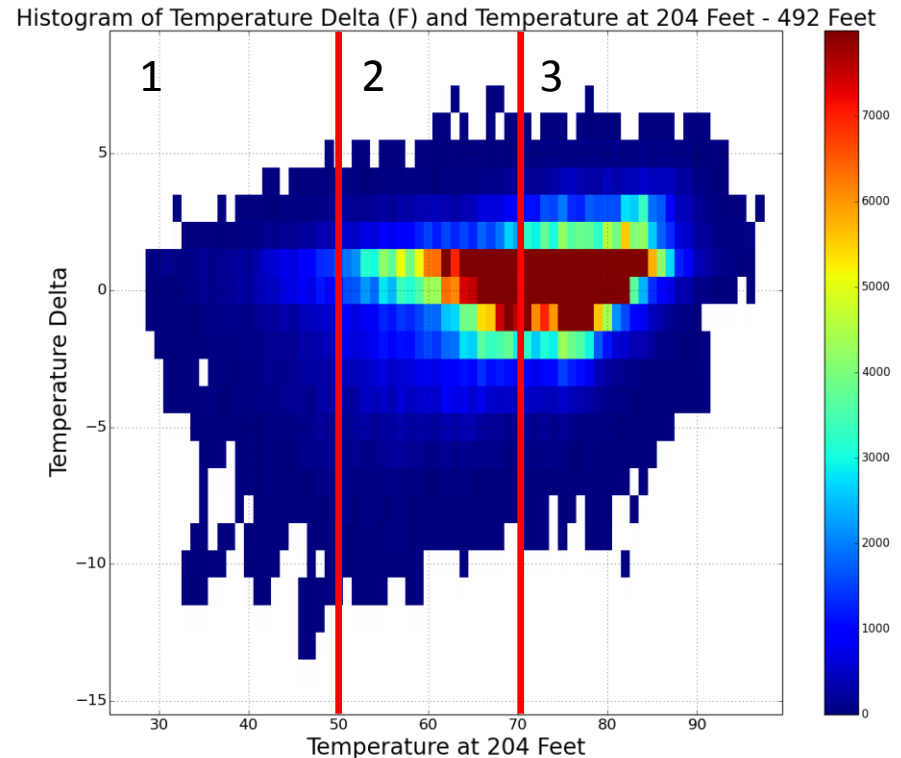
- Selected three approximate temperature regimes: 1) $T_L < 50$ F, 2) $50 \text{ F} \leq T_L \leq 70$ F, 3) $T_L > 70$ F.
- Percent of all T_L : 1) 1.41%, 2) 28.33%, 3) 70.26%.
- Noted a generally stable trend of lapse rates in each regime
 - Upper 99% envelope ~ 2 F (± 1 F).
 - Dry adiabatic lapse is ~ 1.78 F.
- Maximum inversions exceed -9 F in all regimes, but the lower 99% envelope varies across regimes.

- Lower 99% envelopes versus regime
 - 3) -4.10 F to 0.63 F. (smallest range)
 - 2) -10.87 F to -3.06 F. (largest range)
 - 1) -9.38 F to -4.90 F.
- Regimes (2) and (3) contain greater inversion ranges as T_L approach 50 F.
- Regime (1) has a less discernable trend due to the lack of data in this region.

Tower 313 Temperature Deltas (F) 204 ft – 492 ft



- The same temperature regimes were applied to Tower 313.
- Percent of all T_L : 1) 2.32%, 2) 31.02%, 3) 66.67%.
- The lapse rate of the upper envelope of the 99th percentile in regimes (1) and (3) have a trend to increase as T_L increases. Through the regime (2), the lapse rate is stable, being within half a degree (+/-) of 3.85 F.
- Maximum inversions exceed -9.93 F in all regimes, but the lower 99% envelope varies across regimes.



- Lower 99% envelopes versus regime
 - 3) -3.96 F to 0.54 F. (smallest range)
 - 2) -8.28 F to -3.60 F. (largest range)
 - 1) -10.76 F to -4.23 F.
- Regimes (2) and (3) contain greater inversion ranges as T_L approach 50 F.
- Regime (1) has a less discernable trend along the lower 99% envelope due to the lack of data in this region.

Conclusion

- The mean ambient air temperatures from all observed heights were within one degree (+/-) of 72 F. The majority of all temperature deltas (approximately 98.6% at Tower 397 and 97.7% at Tower 313) involve the lower altitude being greater than or equal to 50 F.
- Temperatures and their respective temperature deltas were separated into three regimes:
 - Less than 50 F
 - In between 50 F and 70 F
 - Greater than 70 F
- Both towers illustrated that inversions can occur in all three regimes. However, in temperatures above 50 F, the likelihood of temperature deltas being inversions decreased as temperatures at the lower altitude increased.
- For temperatures below 50 F, a trend correlating between temperature deltas and temperature could not be drawn. In this regime, the lower 99th percentile envelope included inversions ranging from approximately -4 F to -10 F.
- Outside of having more data, the largest difference between Tower 313 and Tower 397 was a difference in trends of the lapse rates. Tower 397 had consistent lapse rates across all three regimes (approximately 2 F). However, Tower 313 had lapse rates that increased with temperature in the lowest and highest regimes.

Back up

Tower 313 and 397 Temperature Deltas (F)

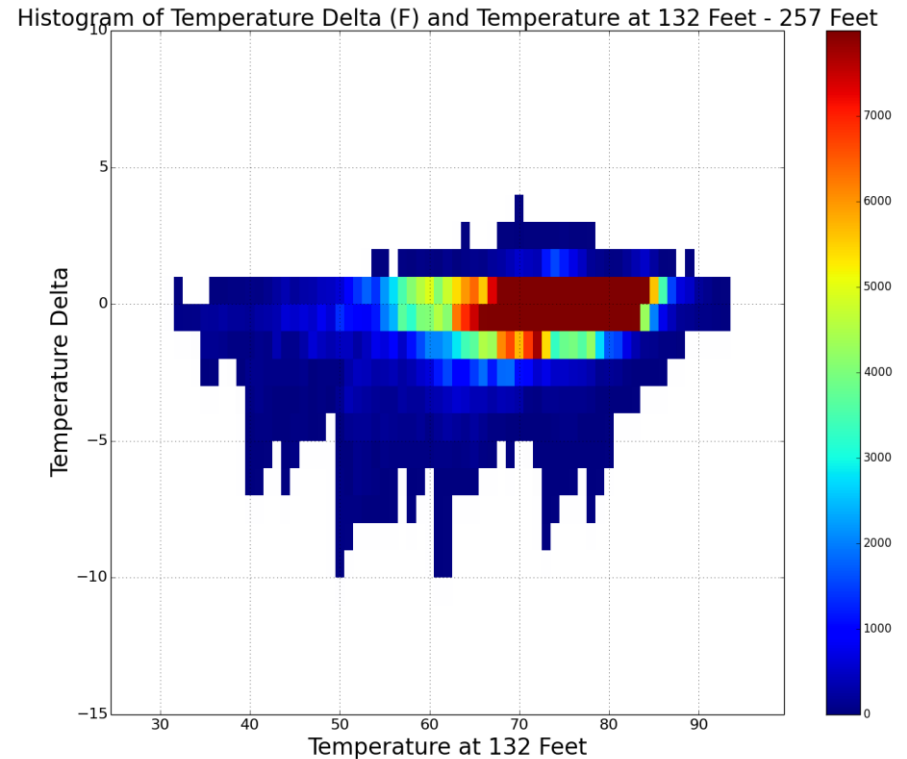
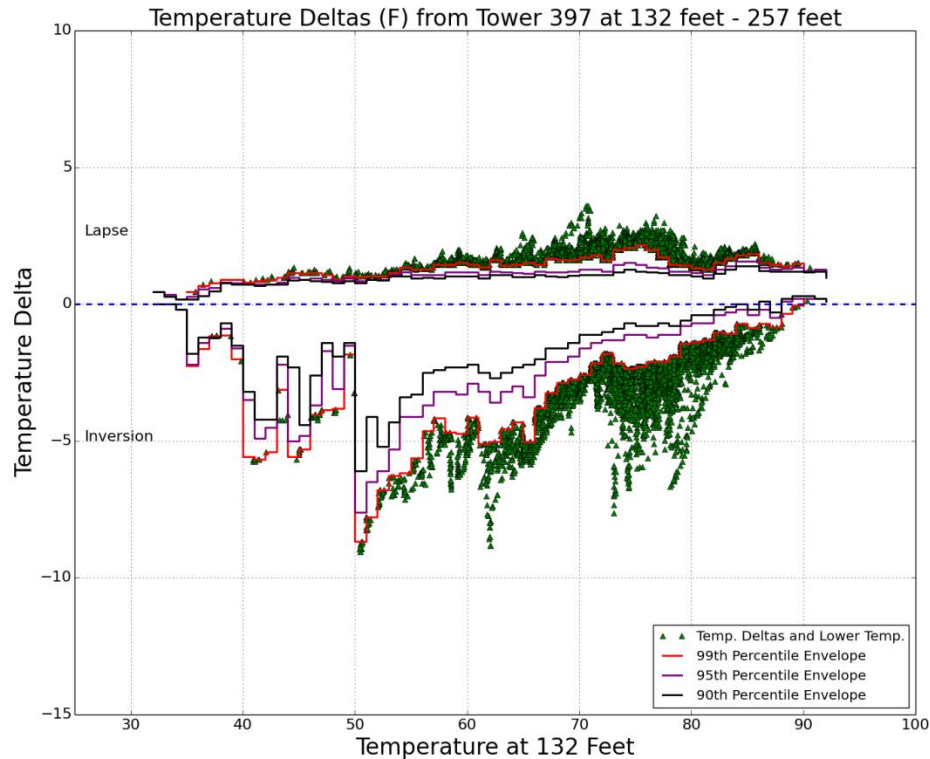
Temperature Delta (Less than 50 F)	Min	Max	Mean
132 - 257 ft	-5.760	1.332	-0.348
132 - 387 ft	-8.136	2.214	-0.265
132 - 457 ft	-9.396	2.610	-0.323
257 - 387 ft	-5.274	1.800	0.175
257 - 457 ft	-6.390	2.286	0.152
387 - 457 ft	-3.294	1.044	0.061

Temperature Delta (50 F to 70 F)	Min	Max	Mean
132 - 257 ft	-9.054	3.150	-0.096
132 - 387 ft	-10.98	5.994	0.136
132 - 457 ft	-11.268	4.572	0.260
257 - 387 ft	-8.694	5.490	0.287
257 - 457 ft	-9.792	3.924	0.421
387 - 457 ft	-7.524	4.500	0.140

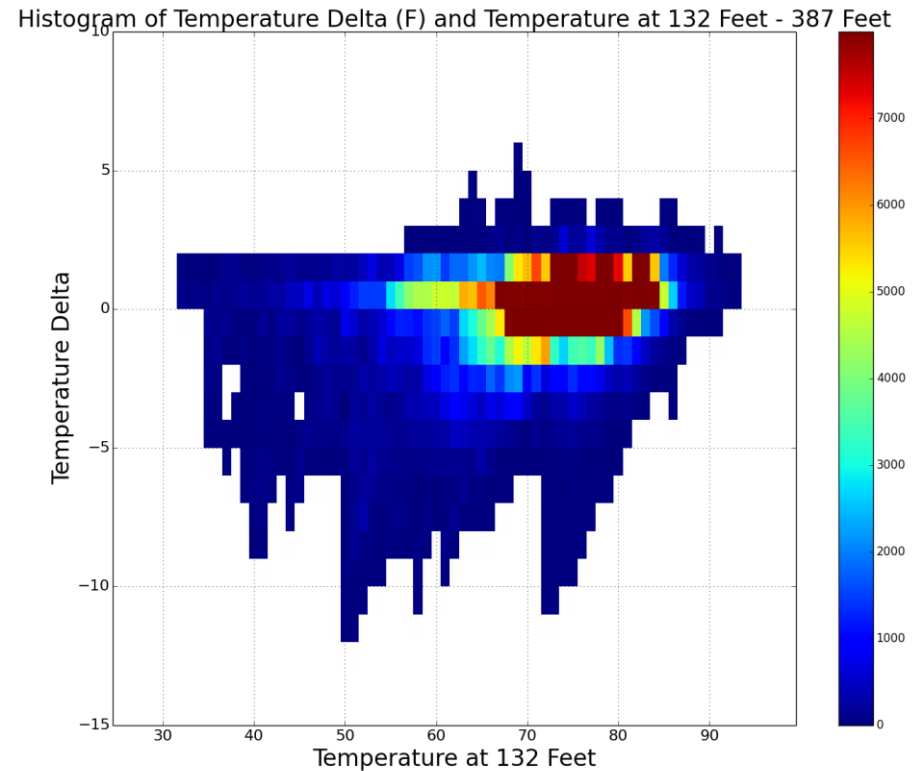
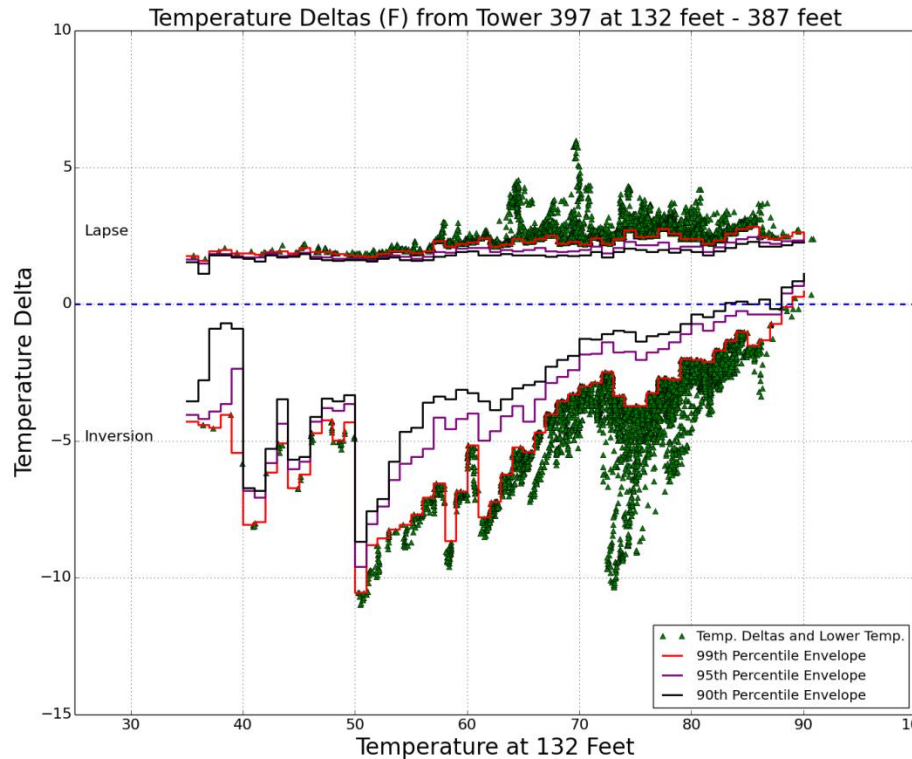
Temperature Delta (Greater than 70 F)	Min	Max	Mean
132 - 257 ft	-7.632	3.160	0.324
132 - 387 ft	-10.332	4.824	0.780
132 - 457 ft	-10.386	4.590	0.973
257 - 387 ft	-6.606	5.940	0.447
257 - 457 ft	-7.074	3.780	0.636
387 - 457 ft	-3.726	2.754	0.185

Temperature Delta Tower 313	Min	Max	Mean
204 - 492 ft (Lesser than 50 F)	-12.96	5.04	-0.14
204 - 492 ft (50 F to 70 F)	-10.80	7.38	0.35
204 - 492 ft (Greater than 70 F)	-9.90	7.38	0.97

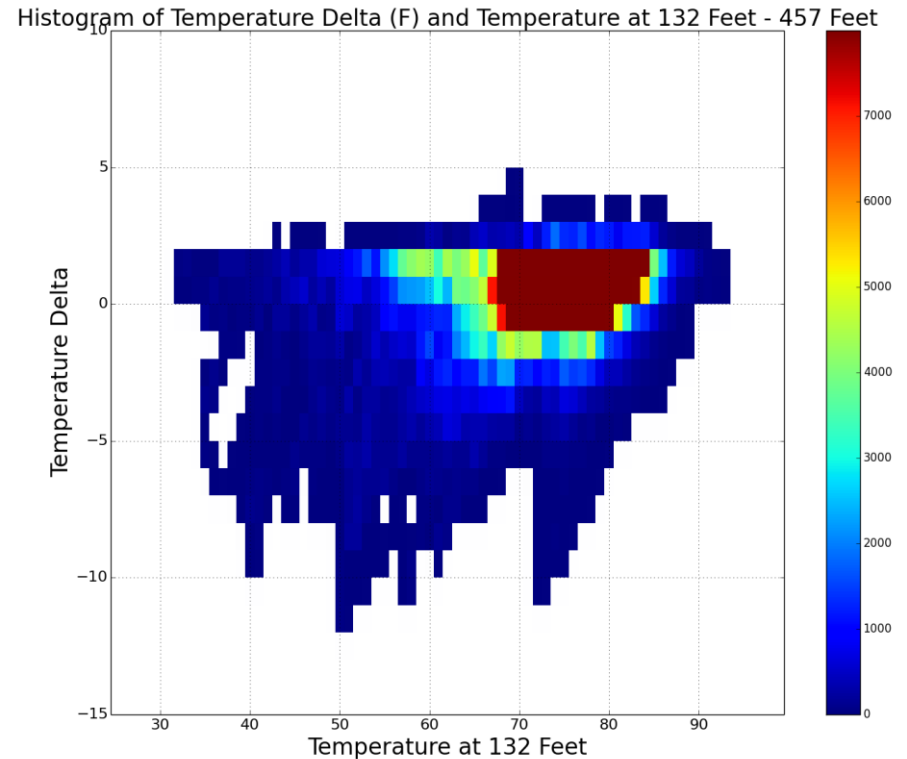
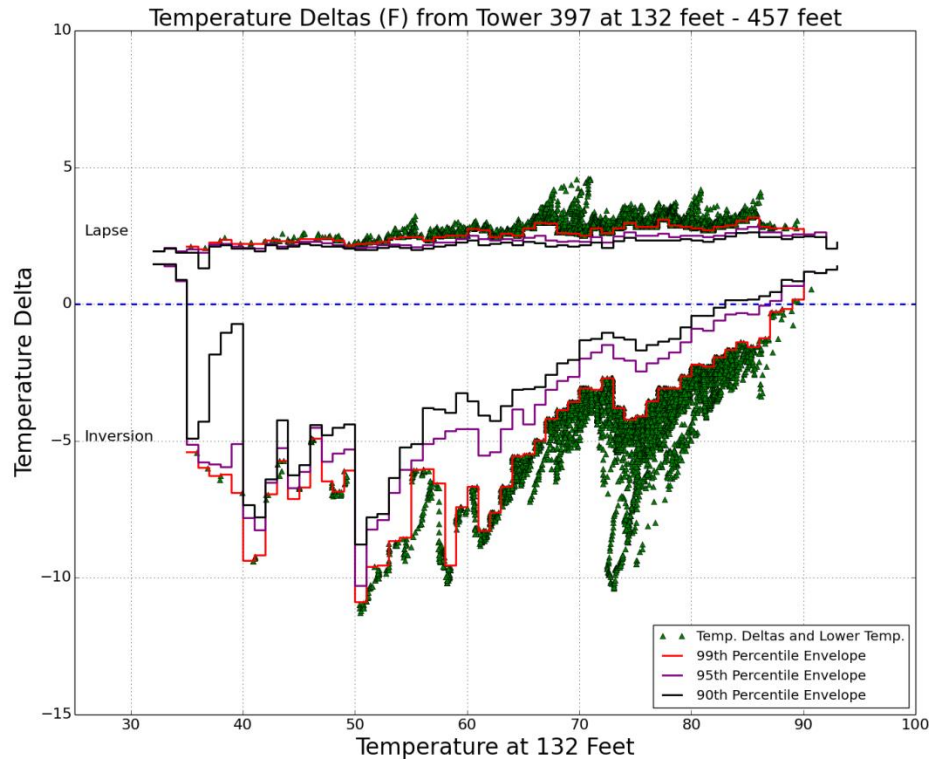
Tower 397 Temperature Deltas (F) 132 ft – 257 ft



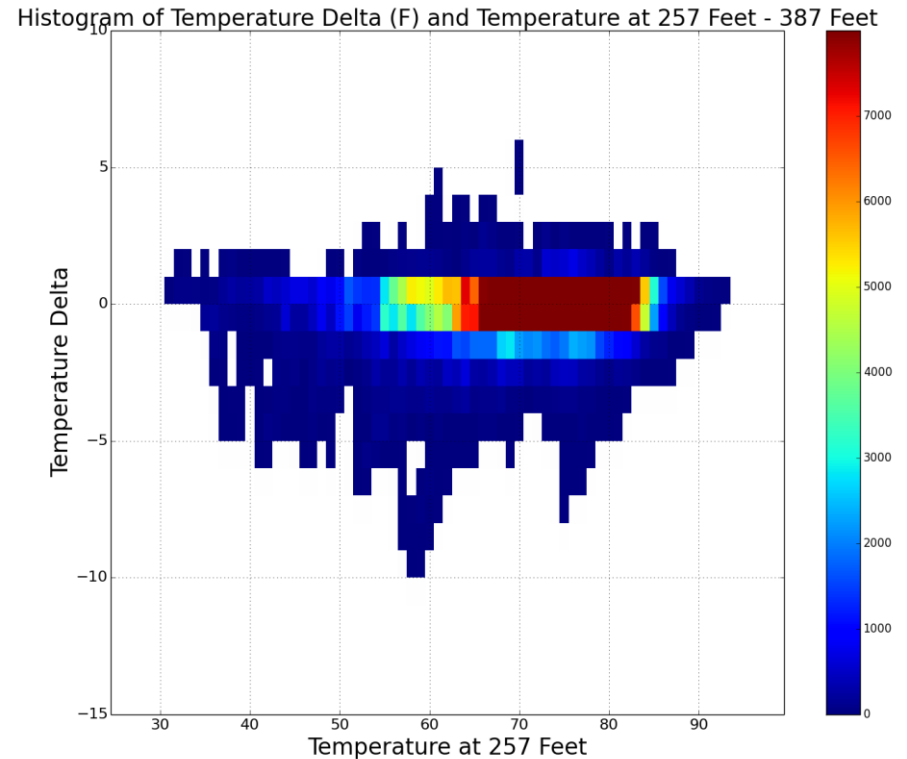
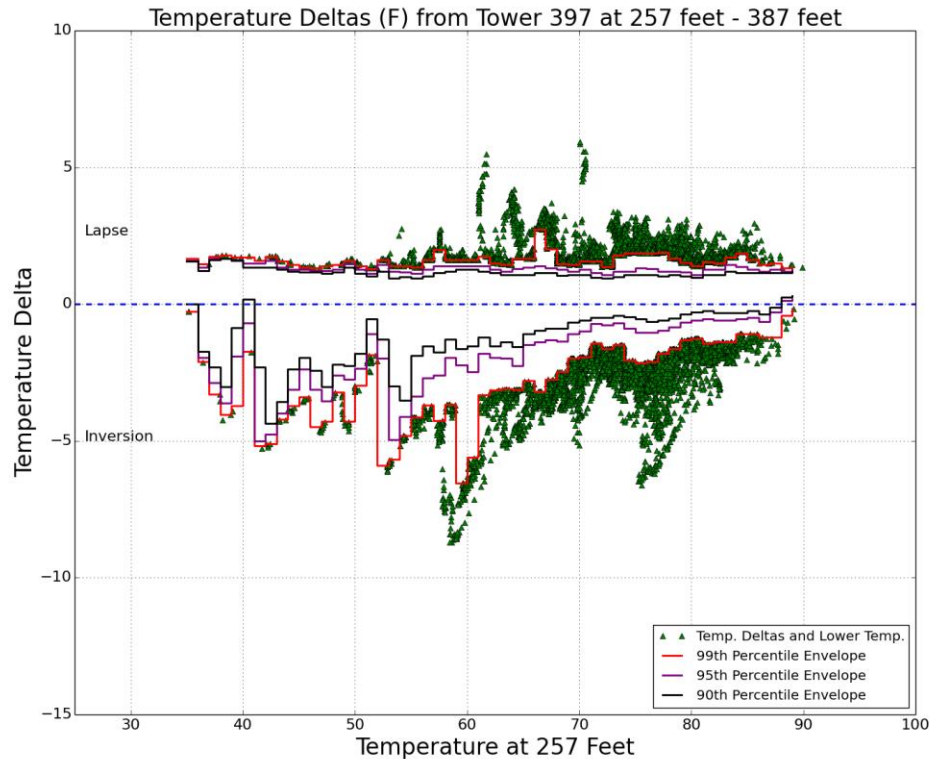
Tower 397 Temperature Deltas (F) 132 ft – 387 ft



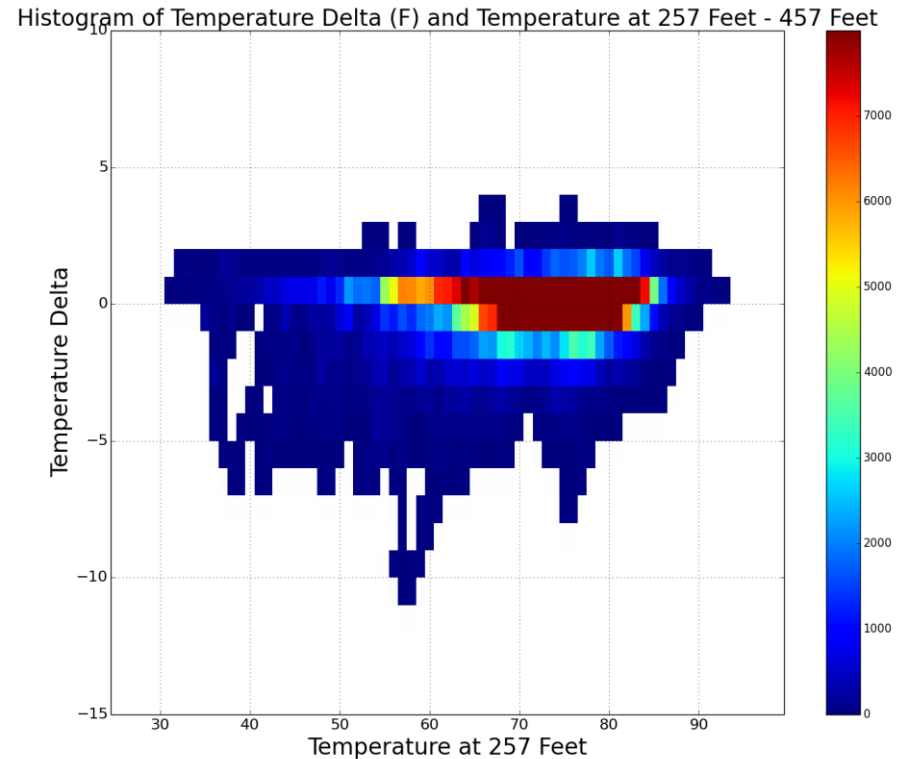
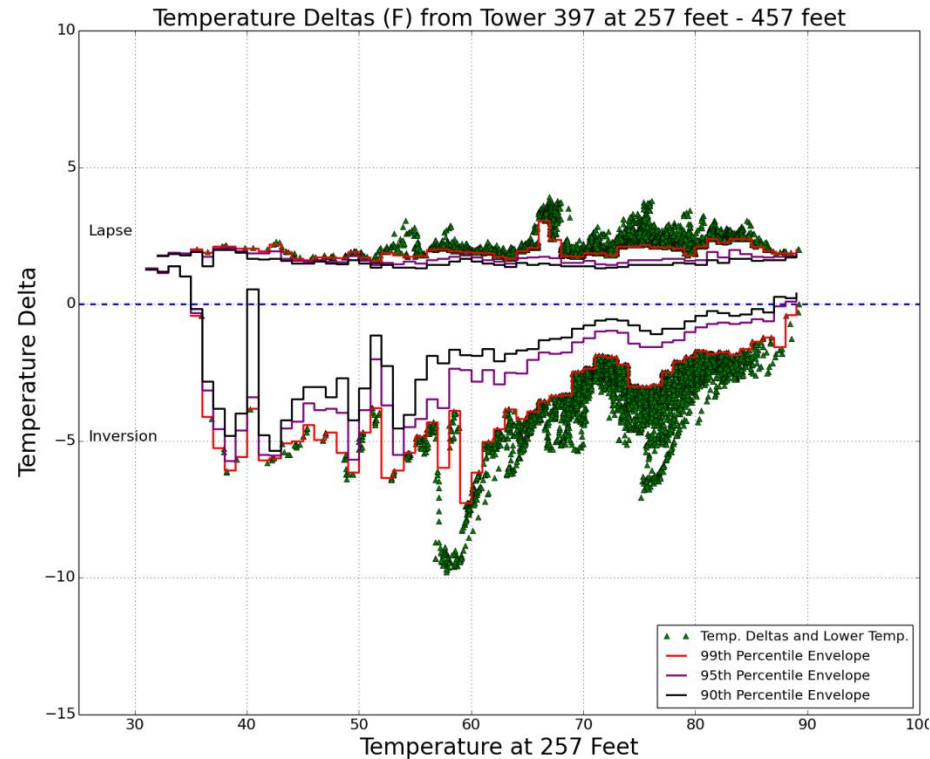
Tower 397 Temperature Deltas (F) 132 ft – 457 ft



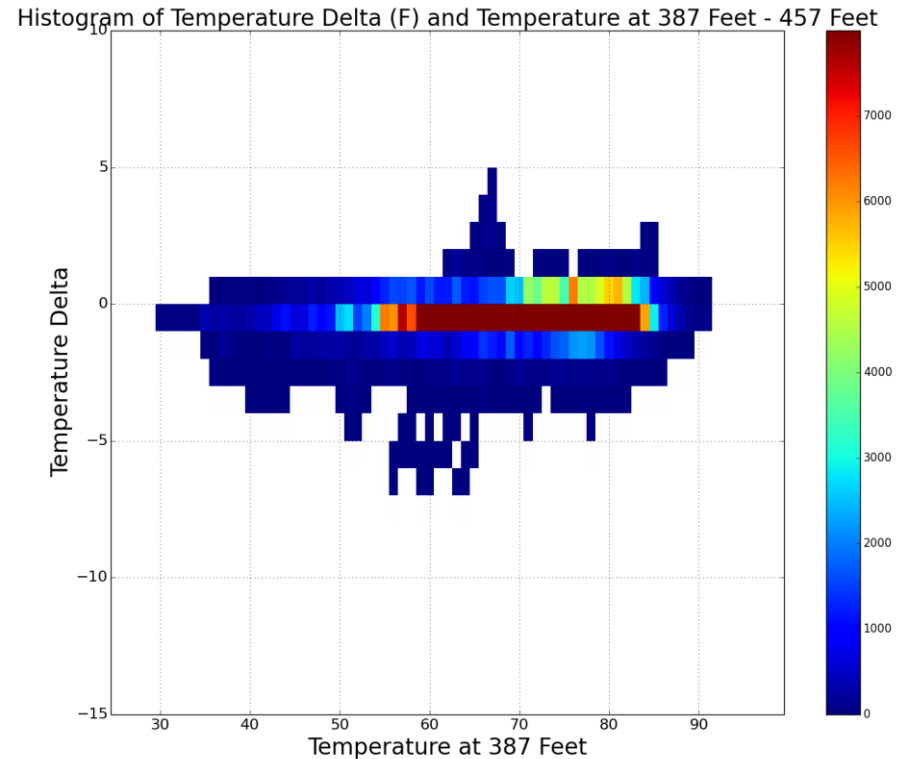
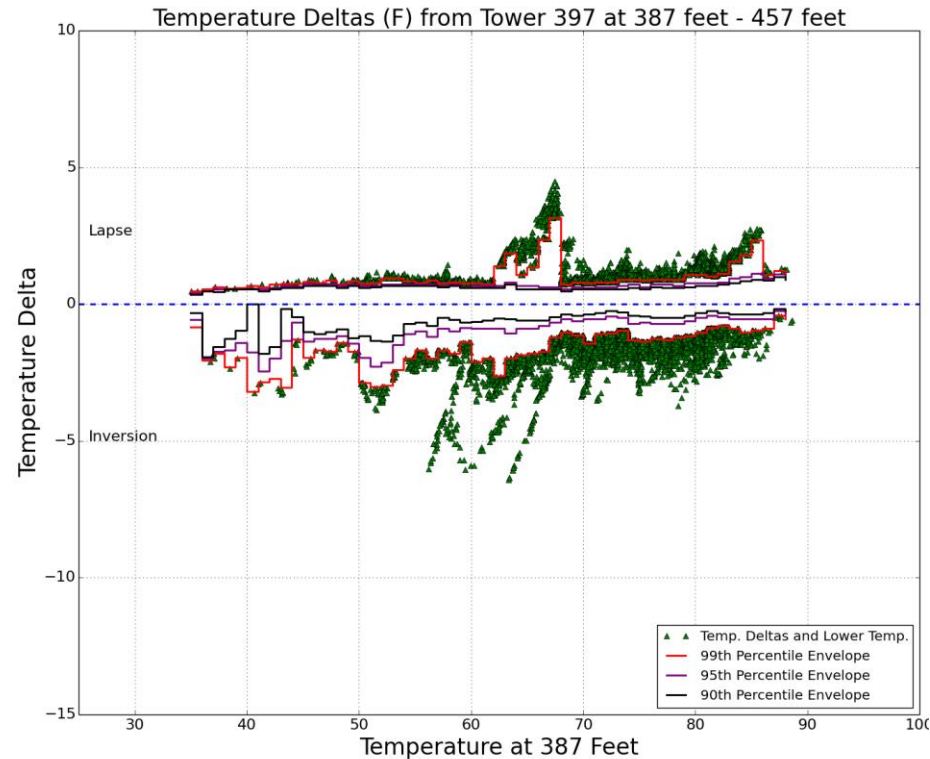
Tower 397 Temperature Deltas (F) 257 ft – 387 ft



Tower 397 Temperature Deltas (F) 257 ft – 457 ft



Tower 397 Temperature Deltas (F) 387 ft – 457 ft



Tower 313 Temperature Deltas (F) 204 ft – 492 ft

